OPEN ACCESS
Pakistan Journal of Agricultural Research

Research Article

Evaluating the Environmental Impacts of Fluoride on the Growth and Physiology of Cotton (*Gossypium hirsutum*)

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Abstract | Environmental pollutants are considered harmful not only to humans but to flora and fauna. Fluoride present in the soil, water or even in the atmosphere may adversely affect plants and ultimately cause serious negative consequences on the development, growth and maturity of crops. In this regard, this study was conducted to examine the possible health effect of fluoride pollution in the form of sodium fluoride on the growth and physiological parameters of cotton plant. The cotton plants were grown in the pots. Six different concentrations of fluoride (3mg/L to 15mg/L) along with water as control were used periodically. At both harvests, maximum growth and physiological functions were recorded at 0mg/L treatment while, reduction was recorded at 15mg/L.

Received | October 29, 2020; **Accepted** | January 13, 2021; **Published** | June 17, 2021
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Citation | Nawaz, M., M. Dawood, K. Javaid, M. Imran, F. Zhao, S. Saima and S.T.H. Shah. 2021. Evaluating the environmental impacts of fluoride on the growth and physiology of cotton (*Gossypium hirsutum*). *Pakistan Journal of Agricultural Research,* 34(3): 425-430.
DOI | https://dx.doi.org/10.17582/journal.pjar/2021/34.3.425.430
Keywords | Fluoride, Impact, Growth, Physiology, Cotton

Introduction

Rapid urbanization across the world increased industrialization which affected the environment through releasing the huge numbers of toxic pollutants. In all pollutants, fluoride (F) ion is found the poisonous pollutant which has adverse effects on both biotic and a-biotic factor of environment (Pent *et al*., 2008; Dolottseva, 2013). According to the study of Dey *et al.* (2012) the major industries which release F into the environment are coal combustion, mining, aluminum manufacture and using F as a fertilizer. Further, the use of fluoride containing pesticides and water with fluoride contents also contributed to environmental pollution. Fluoride is well-known as highly phyto-toxic that easily diffuses in the soil and rapidly absorbed through plants roots when pH of the soil is more acidic (Mustafa *et al*., 2018).

There are two significant ways in which plants exposed to F (Alim *et al*., 2017; Dolottseva, 2013). Fluoride contents can also enter the body of plants through stomatal opening of plants for gaseous exchange through the cells and in the environment (Domingos *et al*., 2003). Fluoride enters the plant through leaves, penetrates the cell wall, and moves to the margins and leaf tip which are essential areas for the evaporation (Mustafa *et al*., 2018). Second exposure way is through the roots of plants. Roots absorb F from the soil (Mackowiak *et al*., 2003). Fluoride moves through xylematic flow to enter the leaves or stem of a plant. Although, stems are considered the least priority place for F to stay in plants (Kamaluddin *et al*., 2004).

The study of (Datta *et al*., 2012; Hong *et al*., 2016) revealed that fluoride pollution can produce the negative impacts on the growth and physiological functions of plants. The F ions inhibit germination, decrease plant's growth, reduces crop's yield, respiration, inhabit metabolism of protein and amino acid, reduce photosynthesis, chlorosis, necrosis and leaf tip burn, decrease in chlorophyll, damage to fruits.

Cotton which belongs to family malvaceae and genus Gossyoium is considered as most value able crop in the world because it is commercially important for producing the fibre in different countries including Pakistan (Cronn *et al*., 2002; Jiwen *et al*., 2012; Shuli *et al*., 2018). Cotton seeds are an important source of fibre, protein, oil, and considered like a nutrients ingredient in human food and animal feed products (Liu *et al*., 2009). It is also used as a renewable bio-fuel (Bellaloui *et al*., 2019; He *et al*., 2013). The main objective of this study was to examine the impacts of fluoride pollution on the biological functions of cotton crop.

Materials and Methods

The experiment was performed in Botanical Garden, Bahauddin Zakaryia University, Multan, during the season of 2019-2020. Certified cotton seeds were collected from the Horticulture department BZU, Multan. Under normal temperature, cotton seeds were germinated. Almost 10 seeds were sown in 50 earthen pots, which were filled with 4kg of sandy loam soil. After 18 days of germination, two seedlings were allowed to grow in every pot. Total six groups viz: 0mg/L was kept as control while 15mg/L was set as maximum treatment of fluoride during the study with three replicates each. Each pot was placed in an open environment. On a daily basis, watering was done. Twice a week, solution of respective concentrations or amounts of sodium fluoride was given throughout an experimental period. First harvesting was done after 75 days and second harvesting was done after 110 days. At each harvest, six plants were taken. Growth and physiological parameters of plants were taken in to account during the research work to ensure the impacts of fluoride on the cotton crop. Statistical analysis was done by using ANOVA with LSD at $P \leq 0.05$.

Results and Discussion

Table 1 showed that F negatively affects the root growth parameters. All levels of treatment exhibited negative effects on the growth parameters in both harvests with the increase of Fluoride. At 1 harvest, maximum fresh and dry weight of root (14.733, 11.333 respectively), and length of root (4.02) were observed at 0mg/L of fluoride application. While lowest fresh and dry weight of root (10.67, 6.33 respectively) and length of root (2.517) were observed at 15mg/L fluoride application. On the other hand, at 2 harvests; maximum (fresh weight of root 20.67), (dry weight of root 13.67) and (length of root 4.83) were recorded at 0mgL fluoride application. While lowest fresh, dry and length of root were observed 14.67, 9.43, 3.43, respectively were observed at 15mg/L fluoride application. Dey *et al.* (2012) found same findings while worked on the young seedlings of Bengal gram. Similarly, Sachan and Lal (2018) for Chickpea (*Cicer arietinum L.*) and barley (*Hordeum vulgare L.*). Onion (*Allium cepa*) was studied by Jha *et al.* (2009). Kamaluddin and Zwiazek (2003) for aspen seedling, Saini *et al.* (2008) for *Prosopis juliflora* and Pant *et al.* (2008) for wheat (*Triticum aestivum*), Table 2 revealed that F negatively affects the shoot growth parameters. The results showed that all levels of F treatment indicated the reduction in growth parameters of plant. During the first harvest fresh and dry weight of shoot (40, 24.83 cm, respectively) and length of shoot (60 cm) were observed maximum at 0mg/L fluoride treatment. While reduced fresh weight of shoot (20cm), dry weight of shoot (12.50) and length of shoot (36.0 cm) were observed at 15mg/L fluoride treatment. On the other hand, during second harvest maximum fresh weight of shoot (35gm), dry weight of shoot (28.50gm) and length of shoot (79.80cm) were observed at 0mgL fluoride application, while lowest value were found for shoot (fresh and dry weight) 25.67, 18.866, respectively for root and (50.0cm) for length of shoot were observed at 15mg/L fluoride application. Singh *et al.* (2017) revealed that increasing levels of fluoride decreased the shoot growth and shoot weight in barley and wheat. Similar results were obtained in *Triticum aestivum var.* Raj. 4083 (Bhargava and Bhardwaj 2010), *Triticum aestivum*, *Cicer arietinum* L. *Brassica juncea* and *Lycopersicon esculentum* (Pant *et al*., 2008), *Cicer arientinum L.* (Dey *et al*., 2012), *Medicago sativa* var. Anand-2 (Brahmbhatt and Patel, 2013).

Table 1: *Impact of various concentrations of fluoride on root fresh weight, roots dry weight and root length.*

Treatment	Harvest	RFW	RDW	RL
0mg/L	1	14.73 DE	11.33 C	4.03 D
3mg/L		14.50 E	9.67 E	3.73 E
6mg/L		13.47 EF	9.50 E	3.43 F
9mg/L		12.50 FG	8.60 F	3.12G
12mg/L		11.67 GH	7.27 G	2.82 H
15mg/L		10.67 H	6.33 H	2.52 I
0mg/L	2	20.67 A	13.67 A	4.83 A
3mg/L		18.33 B	12.67 B	4.63 B
6mg/L		18.30 B	11.92 C	4.33C
9mg/L		17.43 BC	11.57 C	4.03 D
12mg/L		16.30 CD	10.58 D	3.73 E
15mg/L		14.67 E	9.43 E	3.43 F
HSD		1.56	0.62	0.04

Table 2: *Impact of various concentrations of fluoride on shoot fresh weight, shoots dry weight and shoot length.*

Treatment	Harvest	SFW	SDW	SL
0mg/L	1	40 A	24.83 C	60.00 E
3mg/L		37 B	22.50 D	54.00 G
6mg/L		32 D	21.80 D	48.00 I
9mg/L		27.67 G	20.33 E	42.00 J
12mg/L		26 HI	18.50 F	36.00 K
15mg/L		20 J	12.50 G	32.00 L
0mg/L	2	35 C	28.50 A	79.80 A
3mg/L		33 D	26.17 B	73.50 B
6mg/L		30.67 E	24.17 C	68.00 C
9mg/L		29.33 F	22.50 D	62.00 D
12mg/L		27GH	20.17 E	56.00 F
15mg/L		25.67 I	18.87 F	50.00 H
HSD		1.2	1.09	0.81

Table 3 showed that application of F negatively affected the Leaf area and Phosphate starvation response (PSR). The results showed that all levels of F treatment indicated the reduction in leaves area and PSR at both harvest. Leaf area and PSR were gradually decreased as application level of fluoride increased. At first harvest, maximum Leaf area (4.80), and PSR (28.11) were observed at 0mgL Fluoride application. While lowest Leaf area (2.80), and PSR (17.07) were observed at 15mg/L F application. On the other hand, at 2 harvest Maximum Leaf area (6.90) and PSR (42.85) were observed at 0mgL Fluoride application, while lowest Leaf area (5.20) and PSR (31.98) were observed at 15mg/L F application. Similar results have also been demonstrated by Singh *et al*., (2013); Alim *et al*. (2017) and Ahmed *et al*. (2018); Elżbieta *et al*. (2020). According to Hong *et al*. (2016); Justyna *et al*. (2020) fluoride produced negative impacts on the morphology, physiology and even caused death of cells.

Table 3: *Impact of various concentrations of fluoride on leaf area and photo synthetic rate.*

Treatment	Harvest	LA	PSR
0mg/L	1	4.80 G	28.11 G
3mg/L		4.40 H	26.10 H
6mg/L		4.00 I	24.09 I
9mg/L		3.60 J	22.09 J
12mg/L		3.20 K	19.98 K
15mg/L		2.80 L	17.07 L
0mg/L	2	6.90 A	42.85 A
3mg/L		6.60 B	40.77 B
6mg/L		6.30 C	38.47 C
9mg/L		6.00 D	36.20 D
12mg/L		5.60 E	34.09 E
15mg/L		5.20 F	31.98 F
HSD		0.55	8.50

In this study, it has been found that fluoride affected the germination % age, growth and physiological attributes of cotton. During all levels of F treatments, all parameters of plant were reduced significantly. All parameters showed maximum increase at control treatment which is omg/L and with lowest at 15mg/L of treatment. Similar result was obtained in different plants (Chakrabarti *et al*., 2012; Singh *et al*., 2013; Fina *et al*., 2016; Hong *et al*., 2016; Ahmed *et al*., 2018) found such reduced results under the negative influence of fluoride in wheat, rice and barely.

Our results also showed that the fluoride application affected the chlorophyll a and chlorophyll b. The results showed that all levels of fluoride treatment indicated the decrease in the chlorophyll a and b at both harvests. Chlorophyll a and chlorophyll b were gradually decreased as application level of fluoride increased. At both harvests, maximum chlorophyll a and chlorophyll b were observed at 0mgL of treatment of fluoride application. While lowest chlorophyll a and b was found at 15mg/L fluoride application. According to many Authors (Elloumi *et al*., 2005; Sabal *et al*., 2006; Bhargava and Bhardwaj, 2010; Dey *et al*., 2012; Chandra *et al*., 2012; Barnwal *et al*., 2019) when plants were treated with different concentrations of fluoride, then it was found that chlorophyll a and chlorophyll b were decreased.

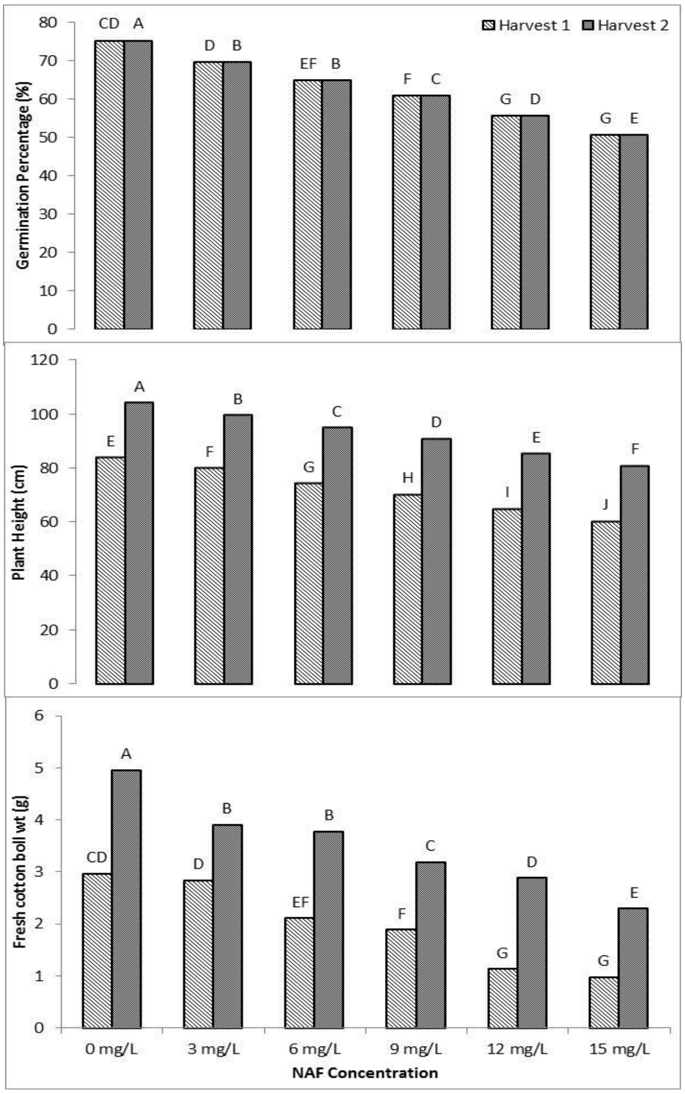

Figure 1: *Effect of NaF on the germination percentage, plant height and fresh cotton boll.*

Acknowledgements

We are very thankful to the director and team of Soil and water Testing Laboratory, Khanewal for helping in sample analysis.

Novelty Statement

Now a day environmental pollution is one of the big problems for health of living organisms, so this research work highlights the need of reducing fluoride emission which is big curse for crops. This work also orients the way of entry of fluoride in crops and reduces the growth.

Author's Contribution

Muhammad Nawaz: Overall planned and handling.
Muhammad Dawood: Statistical analysis.
Kainat Javaid: Collected data and maintained data.
Muhammad Imran: Helped in sample analysis.
Fengliang Zhao: Critical discussion.
Shahzadi Saima: Designed and looked after the experiment.
Syed Tansir Hussain Shah: Helped in laboratory.

Conflict of interest

The authors have declared no conflict of interest.

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